BSC

Engineering Change Notice

Complete only applicable items.

1. QA: QA

170-00C-HA00-00100-000-00B-ECN2

3. Document Identifier:	4. Rev.:	5. Title:	6. ECN:
170-00C-HA00-00100-000	00B	Aging Facility Criticality Safety Calculations	2

7. Reason for Change:
The purpose of this change is to supplement the exisiting Aging Facility criticality safety cases with cases evaluating the 44-BWR Site-Specific Canister/Basket conceptual design

8. Supersedes Change Document: ☐ Yes If, Yes, Change Doc.: ____________ ☒ No

9. Change Impact:

Inputs Changed:	☐ Yes ☒ No	Results Impacted:	☐ Yes ☒ No
Assumptions Changed:	☐ Yes ☒ No	Design Impacted:	☐ Yes ☒ No

10. Description of Change: (Address any "Yes" answers)
Changes are as follows:

1. Cover page needs the following modifications:
-Attachment II title should be One Compact Disc Containing All Files Listed in Attachment I
-Attachment IV needs to be added with the following title: IV. 44-BWR Site-Specific Cansiter/Basket Evaluation
-Attachment V needs to be added as follows: V. One Compact Disc Containing All Files Listed in Attachment IV

2. p. 14 modified to include reference to additional CD

3. pp. 59-64 modified to incorporate additional references

4. p. 65 modified to include two new attachments

5. Attachments IV and V created to supplement existing calculation

A summary list of attachments is as follows:
p. 14; pp. 59-65; pp. IV-1 to IV-8; and V (one CD)

11. Originator: (Print/Sign/Date)
John M. Scaglione 8/18/05

Checker: (Print/Sign/Date)
Cheng T. Hsu 8/18/05

Approved: (Print/Sign/Date)
William E. Hutchins 8/18/05

4. USE OF COMPUTER SOFTWARE

4.1 BASELINED SOFTWARE

4.1.1 MCNP

The MCNP code (CRWMS M&O 1998a) was used to calculate the multiplication factor, k_{eff}, for all systems presented in this report. The software specifications are as follows:

- Program Name: MCNP (CRWMS M&O 1998a)
- Version/Revision Number: Version 4B2LV
- Status/Operating System: Qualified/HP-UX B.10.20
- Software Tracking Number: 30033 V4B2LV
- Computer Type: HP 9000 Series Workstations
- CPU Number: 700887

The input and output files for the various MCNP calculations are contained on CDs (Attachments II and V) and the files are listed in Attachments I and IV.

The MCNP software used was: (1) appropriate for the criticality (k_{eff}) calculations, (2) used only within the range of validation as documented through Briesmeister (1997) and CRWMS M&O (1998b, Section 3.1), and (3) obtained from Software Configuration Management in accordance with appropriate procedures.

4.2 COMMERCIAL OFF-THE-SHELF SOFTWARE

4.2.1 MICROSOFT EXCEL 97 SR-2

- Title: Excel
- Version/Revision Number: Microsoft® Excel 97 SR-2
- This version is installed on a PC running Microsoft Windows 2000 with CPU number 503009

The files for the various Excel calculations are contained on a CD (Attachment II) and the files are listed in Attachment I.

The Excel software was used to calculate weight percent of each component (i.e., ^{235}U, ^{238}U and O) in fresh UO_2 as a function of initial enrichment and to determine Boral loading and thicknesses. Further, the Excel software was also used to calculate weight fractions as well as to illustrate results in Sections 5.2 and 6. The calculations performed with Excel can be reproduced and checked by hand. Excel is exempt from qualification per Section 2.1.6 of LP-SI.11Q, *Software Management*.

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8. ATTACHMENTS

This calculation document includes five attachments:

ATTACHMENT I	Listing of Computer Files (8 pages)
ATTACHMENT II	One Compact Disk Containing All Files Listed in Attachment I (0 pages)
ATTACHMENT III	Sketch of the Aging Pad in the Aging Facility (1 page)
ATTACHMENT IV	44-BWR Site-Specific Canister/Basket Evaluation (8 pages)
ATTACHMENT V	One Compact Disk Containing All Files Listed in Attachment IV (0 pages)

IV. 44-BWR SITE-SPECIFIC CANISTER/BASKET EVALUATION

Sensitivity studies were performed to observe the site-specific canister/basket performance for storage and aging operations in the Aging Facility. A brief description of the sensitivity studies performed and their results are provided.

In each of the sensitivity cases, the site-specific canister/basket dimensions correspond to those from BSC 2005a and BSC 2005b, which are provided in Attachment V. Each configuration is represented with the site-specific canister/basket emplaced inside a waste package or overpack with reflective surfaces consistent with the cases discussed in Section 5.1.5. The design information for the overpack is provided in Section 5.1.5.3, and the waste package dimensions come from BSC 2003d and BSC 2003e which are provided in Attachment V.

IV.1 PARAMETERS

The canister shell was represented as SA-240 S31603 as described in Table 1. The fuel basket plates were represented as Ni-Gd Alloy (Unified Numbering System [UNS] designation is UNS N06464) with 1.5 wt% Gd as described in Table 2, and the thermal shunts were represented as SB-209 A96061 T4 (aluminum 6061) as described in Table 3. The basket side and corner guides, and the basket stiffeners were represented as Grade 70 A 516 carbon steel as described in Table 4. Site-specific canister/basket material thicknesses were taken from the drawings in Attachment IV. The tube to plate separation distance was represented as 0.3170 cm which was derived in BSC (2005c, Attachment IV, file *misc.xls*).

The overpack was represented as described in Section 5.1.5.3 with the overall length adjusted to 635.635 cm in order to accommodate the site-specific canister/basket, and the waste package was represented as described in Attachment V. The value for the length of the overpack was derived based on maintaining the axial dimensions and clearance between the top of the site-specific canister/basket and the bottom of the overpack lid. The waste package consists of two barriers - an inner vessel, and an outer corrosion barrier. The inner vessel was represented as SA-240 S31600 as described in Table 5, and the outer corrosion barrier was represented as Alloy 22 (UNS N06022) as described in Table 6.

The chromium, nickel, and iron elemental weight percents obtained from the references were expanded into their constituent natural isotopic weight percents for use in MCNP. This expansion was performed by: (1) calculating a natural weight fraction of each isotope in the elemental state, and (2) multiplying the elemental weight percent in the material of interest by the natural weight fraction of the isotope in the elemental state to obtain the weight percent of the isotope in the material of interest. This process is described mathematically in Equations 1 and 2. The atomic mass values and atom percent of natural element values for these calculations are from Parrington et al. (1996 [DIRS 103896], pp. 18 to 63).

$$WF_i = \frac{A_i(At\%_i)}{\sum_{i=1}^{I} A_i\left(At\%_i\right)} \qquad \text{(Eq. 1)}$$

where

WF_i = the weight fraction of isotope$_i$ in the natural element
A_i = the atomic mass of isotope$_i$
$At\%_i$ = the atom percent of isotope$_i$ in the natural element
I = the total number of isotopes in the natural element

$$Wt\%_i = WF_i(E_{wt\%}) \quad \text{(Eq. 2)}$$

where

$Wt\%_i$ = the weight percent of isotope$_i$ in the material composition
WF_i = the weight fraction of isotope$_i$ from Equation 1
$E_{wt\%}$ = the referenced weight percent of the element in the material composition

Table 1. Material Specifications for SA-240 S31603

Element/Isotope	ZAID[a]	Wt%	Element/Isotope	ZAID	Wt%
C-nat	6000.50c	0.0300	Fe-54	26054.60c	3.7036
N-14	7014.50c	0.1000	Fe-56	26056.60c	60.2343
Si-nat	14000.50c	0.7500	Fe-57	26057.60c	1.4167
P-31	15031.50c	0.0450	Fe-58	26058.60c	0.1904
S-32	16032.50c	0.0300	Ni-58	28058.60c	8.0641
Cr-50	24050.60c	0.7103	Ni-60	28060.60c	3.2127
Cr-52	24052.60c	14.2291	Ni-61	28061.60c	0.1420
Cr-53	24053.60c	1.6443	Ni-62	28062.60c	0.4596
Cr-54	24054.60c	0.4162	Ni-64	28064.60c	0.1216
Mn-55	25055.50c	2.0000	Mo-nat	42000.50c	2.5000
Density[b] = 7.98 g/cm^3					

Source: ASME 2001, Section II, Part A, SA-240, Table 1

NOTES: [a] ZAID = MCNP material identifier
[b] Density from ASTM G 1-90 (1999, p. 7, Table X1)

Table 2. Material Specifications for Ni-Gd Alloy (UNS N06464) with 1.5 wt% Gd[b]

Element/Isotope	ZAID[a]	Wt%	Element/Isotope	ZAID	Wt%
C-nat	6000.50c	0.0100	Gd-152	64152.50c	0.0029
Mn-55	25055.50c	0.5000	Gd-154	64154.50c	0.0320
Si-nat	14000.50c	0.0800	Gd-155	64155.50c	0.2187
Cr-50	24050.60c	0.6602	Gd-156	64156.50c	0.3045
Cr-52	24052.60c	13.2247	Gd-157	64157.50c	0.2343
Cr-53	24053.60c	1.5283	Gd-158	64158.50c	0.3742
Cr-54	24054.60c	0.3868	Gd-160	64160.50c	0.3335
Ni-58	28058.60c	43.3679	Fe-54	26054.60c	0.0565
Ni-60	28060.60c	17.2778	Fe-56	26056.60c	0.9190
Ni-61	28061.60c	0.7637	Fe-57	26057.60c	0.0216

Table 2. Material Specifications for Ni-Gd Alloy (UNS N06464) with 1.5 wt% Gd[b]

Element/Isotope	ZAID[a]	Wt%	Element/Isotope	ZAID	Wt%
Ni-62	28062.60c	2.4717	Fe-58	26058.60c	0.0029
Ni-64	28064.60c	0.6537	S-32	16032.50c	0.0050
Mo-nat	42000.50c	14.5500	P-31	15031.50c	0.0050
Co-59	27059.50c	2.0000	O-16	8016.50c	0.0050
Density = 8.76 g/cm^3					

Source: ASTM B 932-04 2004, Table 1 and Section 8

NOTE: [a] ZAID = MCNP material identifier
[b] 1.5wt% Gd is based on typical value of 75% credit (NRC 2000 [DIRS 149756], p. 8-4) allowed for fixed neutron absorbers and a nominal Gd loading of 2.0 wt% for Ni-Gd Alloy

Table 3. Material Specifications for SB-209 A96061 T4

Element/Isotope	ZAID[a]	Wt%	Element/Isotope	ZAID	Wt%
Si-nat	14000.50c	0.6000	Mg-nat	12000.50c	1.0000
Fe-54	26054.60c	0.0396	Cr-50	24050.60c	0.0081
Fe-56	26056.60c	0.6433	Cr-52	24052.60c	0.1632
Fe-57	26057.60c	0.0151	Cr-53	24053.60c	0.0189
Fe-58	26058.60c	0.0020	Cr-54	24054.60c	0.0048
Cu-63	29063.60c	0.1884	Ti-nat	22000.50c	0.1500
Cu-65	29065.60c	0.0866	Al-27[b]	13027.50c	96.9300
Mn-55	25055.50c	0.1500	Density[c] = 2.713 g/cm^3		

Source: ASM International 1990, p. 102

NOTES: [a] ZAID = MCNP material identifier
[b] Zn cross-section data unavailable; therefore, it was substituted as Al-27
[c] ASME 2001, Section II, Table NF-2 indicates a converted value from 0.098 lb/in^3 of 2.713 g/cm^3

Table 4. Grade 70 A516 Carbon Steel Composition

Element/Isotope	ZAID[a]	Wt%	Element/Isotope	ZAID	Wt%
C-nat	6000.50c	0.2700	Fe-54	26054.60c	5.5558
Mn-55	25055.50c	1.0450	Fe-56	26056.60c	90.3584
P-31	15031.50c	0.0350	Fe-57	26057.60c	2.1252
S-32	16032.50c	0.0350	Fe-58	26058.60c	0.2856
Si-nat	14000.50c	0.2900	Density = 7.850 g/cm^3		

Source: ASME 2001, Section II, Part A, SA-516/SA-516M, Table 1; Density from ASME 2001, Section II, Part A, SA-20, Section 14.1

NOTE: [a] ZAID = MCNP material identifier

Table 5. Material Specifications for SA-240 S31600

Element/Isotope	ZAID[a]	Wt%	Element/Isotope	ZAID	Wt%
C-nat	6000.50c	0.0800	Fe-54	26054.60c	3.7007
N-14	7014.50c	0.1000	Fe-56	26056.60c	60.1884
Si-nat	14000.50c	0.7500	Fe-57	26057.60c	1.4156
P-31	15031.50c	0.0450	Fe-58	26058.60c	0.1902
S-32	16032.50c	0.0300	Ni-58	28058.60c	8.0641
Cr-50	24050.60c	0.7103	Ni-60	28060.60c	3.2127
Cr-52	24052.60c	14.2291	Ni-61	28061.60c	0.1420
Cr-53	24053.60c	1.6443	Ni-62	28062.60c	0.4596
Cr-54	24054.60c	0.4162	Ni-64	28064.60c	0.1216
Mn-55	25055.50c	2.0000	Mo-nat	42000.50c	2.5000
Density[b] = 7.98 g/cm^3					

Source: ASME 2001, Section II, Part A, SA-240, Table 1

NOTES: [a] ZAID = MCNP material identifier
[b] Density from ASTM G 1-90 (1999, p. 7, Table X1)

Table 6. SB-575 N06022 Material Composition

Element/ Isotope	ZAID[a]	Wt%	Element/ Isotope	ZAID	Wt%
C-nat	6000.50c	0.0150	Co-59	27059.50c	2.5000
Mn-55	25055.50c	0.5000	W-182[b]	74182.55c	0.7877
Si-nat	14000.50c	0.0800	W-183[b]	74183.55c	0.4278
Cr-50	24050.60c	0.8879	W-184[b]	74184.55c	0.9209
Cr-52	24052.60c	17.7863	W-186[b]	74186.55c	0.8636
Cr-53	24053.60c	2.0554	V	23000.50c	0.3500
Cr-54	24054.60c	0.5202	Fe-54	26054.60c	0.2260
Ni-58	28058.60c	36.8024	Fe-56	26056.60c	3.6759
Ni-60	28060.60c	14.6621	Fe-57	26057.60c	0.0865
Ni-61	28061.60c	0.6481	Fe-58	26058.60c	0.0116
Ni-62	28062.60c	2.0975	S-32	16032.50c	0.0200
Ni-64	28064.60c	0.5547	P-31	15031.50c	0.0200
Mo-nat	42000.50c	13.5000	Density = 8.69 g/cm^3		

Source: DTN: MO0003RIB00071.000

NOTES: [a] ZAID = MCNP material identifier
[b] W-180 cross section libraries are not available so the atom percents of the remaining isotopes were used to renormalize the elemental weight and derive isotopic weight percents excluding the negligible 0.120 atom percent in nature contribution from W-180.

The design basis fuel assembly design selected for the site-specific canister evaluations corresponds to that of the GE 8x8 with two water rods described in Section 5.1.5.3. This assembly was selected for use in order to remain consistent with the MPC-68 evaluations.

IV.2 CASE DESCRIPTIONS AND RESULTS

A search for optimum water moderator density within the site-specific canister/basket was performed. This set of cases was used to show that the fuel assemblies placed into a site-specific canister/basket configuration is an under-moderated system. Moderator density values were varied from 0.0 g/cm^3 through 1.0 g/cm^3. The water was represented inside the site-specific canister/basket with void in the external regions. Base case values correspond to a fresh fuel assembly with 5.0 wt% U^{235} initial enrichment. The results of this set of cases are presented in Table 7 and are illustrated in Figure 1.

Table 7. Moderator Density Sensitivity Results

Moderator Density (g/cm^3)	Waste Package		Overpack		Filename[a]
	k_{eff}	σ	k_{eff}	σ	
0.0	0.39861	0.00016	0.34583	0.00020	5.0vv
0.1	0.54034	0.00036	0.52719	0.00036	5.0a
0.2	0.63826	0.00041	0.63388	0.00046	5.0b
0.3	0.71584	0.00047	0.71283	0.00046	5.0c
0.4	0.77361	0.00050	0.77313	0.00050	5.0d
0.5	0.82043	0.00052	0.81786	0.00057	5.0e
0.6	0.85501	0.00056	0.85400	0.00049	5.0f
0.7	0.88390	0.00056	0.88269	0.00056	5.0g
0.8	0.90711	0.00056	0.90722	0.00054	5.0h
0.9	0.92636	0.00049	0.92636	0.00055	5.0i
1.0	0.94189	0.00055	0.94154	0.00057	5.0wv/5.0wvv

NOTE: [a] Filenames are the same but are contained in a unique directory structure in Attachment V

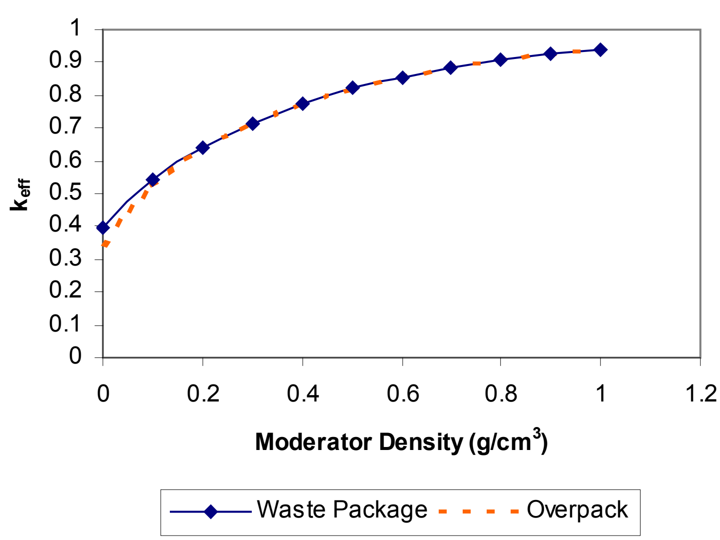

Figure 1. Moderator Density Sensitivity Results

Additional cases observing k_{eff} under different reflector conditions was also performed. The cases evaluated are for water, void, or both in different regions within the configuration. The results of this set of cases are presented in Table 8.

Table 8. Reflector Sensitivity Results

Case Description	Waste Package		Overpack		Filename[a]
	k_{eff}	σ	k_{eff}	σ	
Case with water in all void regions. Represents a scenario where the site-specific canister and waste package or overpack are flooded and submerged in water moderator	0.94307	0.00057	0.94210	0.00052	5.0ww
Case with void in all void regions. Represents nominal storage conditions where there is no moderator present	0.39861	0.00016	0.34583	0.0002	5.0vv[b]
Case where the site-specific canister remains dry internally, but moderator is present around it	0.35222	0.00020	0.32965	0.00018	5.0vw[b]
Case where the site-specific canister remains dry internally, and dry inside the overpack but moderator is present around it	Not applicable	Not applicable	0.34568	0.00018	5.0 vvw
Case where full density water moderator is inside the site-specific canister but a dry environment surrounding it	0.94189	0.00055	0.94154	0.00057	5.0 wv/5.0wvv

NOTES: [a] Filenames are the same but are contained in a unique directory structure in Attachment V
[b] The water reflector cases show lower k_{eff} values than the void cases due to reflective surfaces placed 15 cm in the radial direction from the outer surface of the waste package and overpack

The results show that the cases with or without moderator present are below the USL value of 0.9472 (See Assumption 3.11). Under normal operations it is expected that there will not be any moderator present within the site-specific canister/basket. Since there are no event sequences identified for the aging facility, the fully flooded cases, which are evaluated to demonstrate the defense in depth features of the design, are expected to bound any category one or two event sequence.

The corresponding MCNP input and output files for the cases used in this evaluation are provided electronically in Attachment V in ASCII format. The following is a listing of the input and output file names for the MCNP calculations. Filenames with an "O" at the end are output files.

Date	Time	File Size	File Name
8/15/2005	04:38p	297,204	000-M0K-HA00-00202-000-00A.pdf
8/15/2005	04:39p	233,735	000-M0K-HA00-00203-000-00A.pdf
4/5/2005	03:48p	382,464	000-MW0-DNF0-00102-000-00A.pdf
4/5/2005	03:48p	345,088	000-MW0-DNF0-00103-000-00A.pdf
8/16/2005	04:34p	112,931	\WP\5.0a
8/16/2005	04:34p	622,326	\WP\5.0aO
8/16/2005	04:34p	112,922	\WP\5.0b
8/16/2005	04:34p	470,743	\WP\5.0bO
8/16/2005	04:34p	112,922	\WP\5.0c
8/16/2005	04:34p	470,321	\WP\5.0cO
8/16/2005	04:34p	112,922	\WP\5.0d
8/16/2005	04:34p	469,563	\WP\5.0dO
8/16/2005	04:34p	112,922	\WP\5.0e
8/16/2005	04:34p	468,453	\WP\5.0eO
8/16/2005	04:34p	112,922	\WP\5.0f
8/16/2005	04:34p	468,251	\WP\5.0fO
8/16/2005	04:34p	112,922	\WP\5.0g
8/16/2005	04:34p	468,939	\WP\5.0gO
8/16/2005	04:34p	112,922	\WP\5.0h
8/16/2005	04:34p	468,939	\WP\5.0hO
8/16/2005	04:34p	112,922	\WP\5.0i
8/16/2005	04:33p	467,151	\WP\5.0iO
8/16/2005	04:33p	112,771	\WP\5.0vv
8/16/2005	04:33p	479,029	\WP\5.0vvO
8/16/2005	04:33p	112,777	\WP\5.0vw
8/16/2005	04:33p	479,071	\WP\5.0vwO
8/16/2005	04:33p	112,922	\WP\5.0wv
8/16/2005	04:33p	466,397	\WP\5.0wvO
8/18/2005	11:49a	112,941	\WP\5.0ww
8/18/2005	11:49a	466,197	\WP\5.0wwO
8/17/2005	07:56a	111,718	\Overpack\5.0a
8/17/2005	07:56a	467,758	\Overpack\5.0aO
8/17/2005	07:56a	111,723	\Overpack\5.0b
8/17/2005	07:56a	467,678	\Overpack\5.0bO
8/17/2005	07:56a	111,699	\Overpack\5.0c
8/17/2005	07:56a	466,842	\Overpack\5.0cO
8/17/2005	07:56a	111,723	\Overpack\5.0d
8/17/2005	07:56a	463,922	\Overpack\5.0dO
8/17/2005	07:56a	111,723	\Overpack\5.0e
8/17/2005	07:56a	466,286	\Overpack\5.0eO
8/17/2005	07:56a	111,723	\Overpack\5.0f
8/17/2005	07:56a	466,286	\Overpack\5.0fO
8/17/2005	07:56a	111,723	\Overpack\5.0g
8/17/2005	07:56a	465,874	\Overpack\5.0gO

Date	Time	File Size	File Name
8/17/2005	07:56a	111,723	\Overpack\5.0h
8/17/2005	07:56a	464,974	\Overpack\5.0hO
8/17/2005	07:56a	111,723	\Overpack\5.0i
8/17/2005	07:56a	464,186	\Overpack\5.0iO
8/17/2005	07:56a	111,577	\Overpack\5.0vv
8/17/2005	07:56a	474,474	\Overpack\5.0vvO
8/17/2005	07:56a	111,585	\Overpack\5.0vvw
8/17/2005	07:56a	474,302	\Overpack\5.0vvwO
8/17/2005	07:56a	111,596	\Overpack\5.0vw
8/17/2005	07:56a	474,370	\Overpack\5.0vwO
8/18/2005	11:50a	111,727	\Overpack\5.0wvv
8/18/2005	11:50a	463,553	\Overpack\5.0wvvO
8/17/2005	07:56a	111,742	\Overpack\5.0ww
8/17/2005	07:56a	464,462	\Overpack\5.0wwO